EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN - PS DIVISION

CERN/PS 2002-043(AE)
CLIC Note 525

STATIC BEAM-BASED ALIGNMENT OF THE RF STRUCTURES IN THE CLIC MAIN LINAC

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Abstract

In the Compact Linear Collider (CLIC), it is planned to use an active micro-mover system in order to align the components of the main linac with an accuracy in the micrometre range. This active alignment system has already been successfully tested in CTF2. The effectiveness of such an alignment system is simulated for different hardware configurations and correction algorithms.

EPAC2002 Conference, 3-7 June, 2002, Paris, France

Geneva, Switzerland
3 July 2002

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Abstract

In the Compact Linear Collider (CLIC), it is planned to use an active micro-mover system in order to align the components of the main linac with an accuracy in the micrometre range. This active alignment system has already been successfully tested in CTF2 [1]. The effectiveness of such an alignment system is simulated for different hardware configurations and correction algorithms.

1 INTRODUCTION

In the main linac of CLIC, the RF structures are supported by girders which form a continuous chain along the linac. The hardware configuration used for the present simulation relies on having quadrupoles and beam position monitors (BPMs) supported independently of the girder. In the prealignment scheme for the main linac of CLIC, the beamline elements will be aligned by means of a sophisticated system consisting of wires, optical line components and hydrostatic levelling [2]. This should allow misalignment r.m.s. amplitudes of the order of 10 μm. Then, a beam-based alignment (ballistic method [3]) of the BPMs and of the quadrupoles, followed by the RF structures alignment and then by the emittance-tuning bumps are necessary to maintain the emittance growth smaller than 100 %. In these studies, the RF structure alignment was made assuming that each structure can be aligned separately with a precision of 10 μm. In this paper, we investigate a more complete model for the RF structure alignment. For this, we assume that the RF structures are misaligned. There is then an emittance growth, mainly due to the transverse wakefields in the RF structures induced by their offsets around the beamline. In order to minimise the r.m.s. scattering of the RF structures, and therefore the emittance growth, a procedure of girder alignment is under study.

Two consecutive girders are linked by connectors at an articulation point. In order to measure the transverse position of the RF structure relative to the beamline, the central cell of the structure may be used as a beam position monitor (RFM : RF Monitor). The girder alignment procedure is sensitive to the following errors :

- The misalignment of the RF structures on the girders
- The position error of the connection point of each girder at the articulation point
- The scattering of the articulation point along the linac
- The error of the beam position monitor inside the RF structure (RFM)

All these errors for the alignment are shown in Fig. 1. We have to mention that the first 3 error sources come from the prealignment precision, but the last is a property of the RF structure. The connection of one girder at the articulation point can be done in principle with a precision of a few microns. The r.m.s. scattering of the articulation points along the linac should be of the order of 10 μm [2]. From the NLC investigations [4], the RFM precision was found to be of the order of 5 μm, and in CLIC we have always considered 10 μm. Ongoing studies should allow us to estimate more accurately the RFM precision for CLIC RF structures [5].

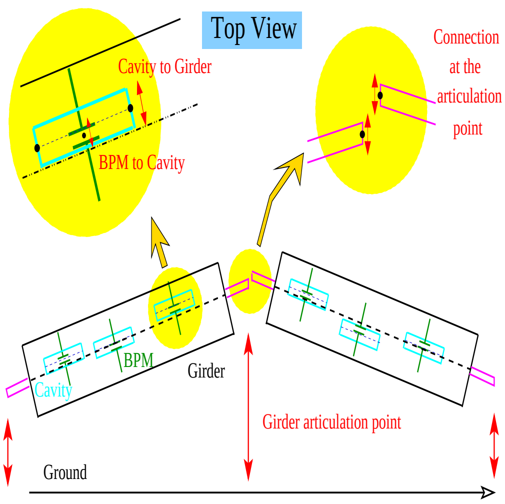

Figure 1: Alignment error sources.

2 CORRECTION PROCEDURE

The linac is divided into bins of length k with the first bin at the entrance of the linac. Each bin contains k quadrupoles. The bin starts with its first quadrupole and ends before the quadrupole of the next bin. We investigate two possible hardware configurations. In the first, all girders form a continuous chain in the linac. The bins are then connected, which means that the last girder of a bin has the same articulation point as the first girder of the next bin.

For the second hardware configuration, bins are disconnected. This can be achieved by having one more articulation point, which allow the last girder of a bin and the first girder of the next bin to move independently (Fig. 2).

In the Table 1, the number of bins L and the number of

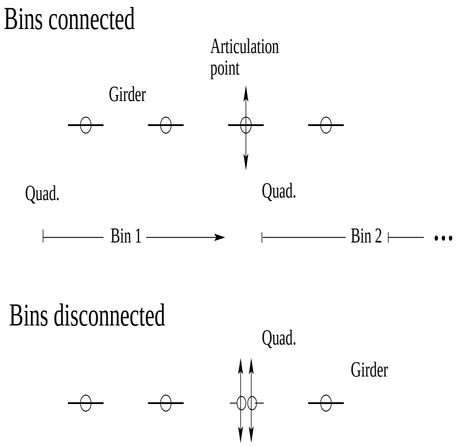

Figure 2: Hardware configuration.

articulation points n_a required to move the girders in the vertical plane is shown for different hardware configurations of the CLIC main linac.

Configuration	L	n_a
Bins disconnected, k=1	1324	7447
Bins connected, k=1	1324	6268
Bins connected, k=5	265	6268

Table 1: Number of bins L and of articulation points n_a required for different hardware configurations used in the girders alignment procedure.

The alignment procedure minimises the r.m.s. scattering of the RF structures around the beamline in each bin by moving the articulation points. Consider a linac divided into L bins. In a given bin l (l=1,...,L), there are N_l girders and in each girder j (j=1,..,N_l) there are $M_{l,j}$ RF structures. i_j is the i^{th} RF structure of the girder j and $\delta_{i,j}$ is the distance of the RF structure i_j to the beamline (given by the readings of the RFM). The alignment is done by minimising the related functions S_l from the first bin of the linac to the last one :

$$S_l = \sum_{j}^{N_l} \sum_{i}^{M_{l,j}} \delta_i^2$$

The girder alignment is immediately followed by a few-to-few quadrupole correction.

3 RESULTS

The results concerning these studies have been obtained by using PLACET [6]. The simulations have been performed with a single bunch beam containing 4×10^9 particles. The bunch length is 35 μm and the vertical emittance is ϵ_y = 5 nm at the entrance of the linac. Only results concerning the vertical emittance are presented since the horizontal one is larger and thus much less sensitive to misalignment errors. The results have been obtained by averaging over 100 machines. The present results have been obtained with the configuration of disconnected bins of bin length k=1.

3.1 RF structures on girder misalignment

Consider a perfect linac, except that the positions of the RF structures on the girders follow a normal distribution with σ=10 μm. In this case, the emittance growth $\Delta\epsilon_y/\epsilon_y$ is 599 % at the end of the linac. If, now, the alignment procedure is used, $\Delta\epsilon_y/\epsilon_y$ is reduced to 0.1 %, because the averaged offset of the RF structures in each bin is zero, so the wakefield kick is cancelled. The remaining emittance growth is just due to the small residual dispersion of the RF structures offsets in the bins. For σ= 20 μm, the emittance growth after correction is 0.6 %.

3.2 Misalignments of the articulation points

In this section, in addition to a 10 μm RF structure scattering, we start with a very large misalignment of the articulation points of 100 μm and 200μm. This will lead to a huge emittance growth of 189 $\times$ 10^3 % and 752 $\times$ 10^3 % respectively. After correction, we expect a very small effect of this misalignment, since the alignment girder should correct for it. To check, we simulate the correction in these cases. We found that the girder alignment brings the emittance growth down to 0.5 % and 1.5 % respectively if a single correction is performed. The correction can be repeated to improve the performance. After the second correction, the emittance growth is 0.1 % for both cases. This two step iterative correction is always used thereafter.

As already mentioned above, the residual emittance growth of 0.1 % is due to the small r.m.s. amplitude of the RF structures remaining in the bins. We see then that the misalignment of the articulation points relative to the beamline is perfectly corrected whatever is the misalignment amplitude. Henceforth, the reference beamline used for our studies will be given by a perfect linac with a dispersion of 10 μm for the RF structures and 100 μm for the articulation points.

3.3 Position errors of girder connections

In addition to the reference beamline, we consider that each girder is connected independently at the articulation point. The position errors are assumed to follow a normal distribution with σ varying from 5 μm to 20 μm. For σ=5 μm, the correction brings $\Delta\epsilon_y/\epsilon_y$ to 0.2 % (instead of 0.1 % for the reference beamline). For σ=20 μm, $\Delta\epsilon_y/\epsilon_y$=1.1 %. All the results are given in Table 2.

3.4 Position errors of the BPM inside the RF structures

Starting from the reference beamline, the RFMs are scattered around the centre of the RF structure. The emittance growth becomes rapidly huge when σ increases in the range of some microns. For σ=5 μm, $\Delta\epsilon_y/\epsilon_y$=96.2 %. Table 2 summarises all the results obtained with the correction. We clearly see that the RFM misalignment can be a tight tolerance for the girder alignment.

Errors	Bin Configuration		
	disconnected	connected	
	k=1	k=1	k=5
Initial	0.1 %	9.1 %	2.9 %
Connectors :			
σ=5 μm	0.2 %	14.4 %	4.9 %
σ=10 μm	0.4 %	-	-
σ=20 μm	1.1 %	94.6 %	35.8 %
RFM :			
σ= 5 μm	96.2 %	105.7 %	99.9 %
σ= 10 μm	368 %	-	-
σ= 20 μm	1440.8 %	1477.2 %	1450.1 %

Table 2: Emittance growth obtained after correction for different error sources added to the reference beamline.

3.5 Disconnected bins

Here we discuss the results obtained with connected bins with a bin length of k=1 and k=5. We see that using connected bins decreases the performance of the girder alignment for RF structure on girders and of the girder connections misalignment. It comes from the fact that the end extremity of the last girder of a bin is misaligned when the next bin is aligned. By increasing the bin length, this effect is minimised and we can achieve a small emittance growth, as seen in the different results shown in Table 2.

The results concerning the RFM position errors show that the hardware configuration does not make any difference. Bins connected or disconnected, and different bin length, give very similar results.

4 EMITTANCE-TUNING BUMPS

A further reduction of the emittance growth can be achieved by applying emittance-tuning bumps [7, 8]. We first consider the perfect linac with only the RF structures scattered (σ=10 μm) and without girder alignment. As already mentioned, the emittance growth is 599 %. If 10 bumps are applied, the emittance growth reduces to 17.1 %.

Now, we apply the emittance-tuning bump (10 bumps) after the girder alignment has been performed, with bins disconnected and k=1. For the reference beamline, the emittance growth goes from 0.1 % to zero. All kinds of imprecision in the BPM inside the RF structure (RFM) may result in a large emittance growth, even after the bumps correction. For example, if σ=10 μm, the emittance growth is still of 17 % (before bumps $\Delta\epsilon_y/\epsilon_y$=368 %). If σ=20 μm, then $\Delta\epsilon_y/\epsilon_y$=68 %.

Next we investigate the results obtained with the connected bins of bin length k=1, i.e. the cases where a large emittance growth remained after the girder alignment (see Table 2). We discuss the results for all the error sources added to the reference beamline. If we consider the RFM errors, then with a precision in the positioning of 5 μm, the emittance growth reduces to a small value of 5.7 % after the girder alignment and the 10 bumps. For σ = 20 μm, $\Delta\epsilon_y/\epsilon_y$=73.0 %, and then we see that the hardware configuration used for girder alignment is not important for the RFM errors. With a scattering of σ=5μm for the connectors at the articulation point, we find $\Delta\epsilon_y/\epsilon_y$=1.4 %. For σ=20μm, $\Delta\epsilon_y/\epsilon_y$=9.4 %. For connected bins, but with a bin length k=5, $\Delta\epsilon_y/\epsilon_y$=5.3 %. So, a larger bin length improves significantly the performances of the alignment in this case.

So, the emittance-tuning bumps considerably reduce the emittance growth. The connector positioning errors are not completely negligible but remain rather small. The main contributions to $\Delta\epsilon_y/\epsilon_y$ are from the RFM scattering.

5 CONCLUSION

In this paper, the tolerances for different error sources have been investigated. It has been shown that the misalignment of the articulation points does not induce any emittance growth because the girder alignment allows a perfect correction. The connections at the articulation points may have a contribution to the emittance growth but can be greatly reduced by applying the emittance-tuning bumps. In the realistic case of σ=5μm, the emittance growth is only of the order of 1 %. The hardware configuration for girder alignment plays an important role for these errors. Bins disconnected or a rather longer bin lenth in connected bins are preferred. We have also see that the major contribution to $\Delta\epsilon_y/\epsilon_y$ comes from the misalignment of the BPMs inside the RF structure, even after the emittance-tuning bumps. For these errors, the hardware configuration of the girder alignment is not important.

6 REFERENCES

[1] M. Benedetti, D. Carrica, W. Coosemans, R. Pittin, CLIC Note 361.

[2] W. Coosemans, Private communication.

[3] T.O. Raubenheimer, D. Schulte, PAC99, New York, USA (1999).

[4] C. Adolphsen *et al*, PAC99, New York, USA (1999).

[5] Ongoing thesis by J. Prochnow.

[6] E.T. d'Amico, G. Guignard, N. Leros, D. Schulte, CERN/PS 2001-028(AE) and PAC01.

[7] D. Schulte, EPAC98, Stockholm, Sweden (1998).

[8] CLIC Study Team, G. Guignard editor, CERN 2000-008 (2000).